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WATER RESOURCES STUDY AND PUBLIC HEALTH ASPECTS OF THE WHEATLAND UNIT - LARAMIE DIVISION, WYOMING: STUDY OF EFFECT OF PROJECT DEVELOPMENT WATER QUALITY, NEEDS AND VALUE OF WATER FOR THE PURPOSE OF WATER QUALITY CONTROL, AND THE PUBLIC HEALTH ASPECTS OF THE WHEATLAND UNIT, LARAMIE DIVISION - WYOMING, BUREAU OF RECLAMATION, REGION 7

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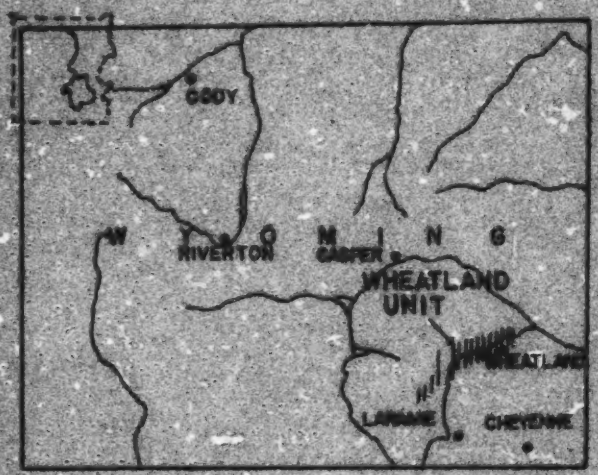
WATER RESOURCES STUDY
and
PUBLIC HEALTH ASPECTS
of the
WHEATLAND UNIT - LARAMIE DIVISION
WYOMING

Study of Effect of Project Development on Water Quality, Needs and Value of Water for the Purpose of Water Quality Control, and the Public Health Aspects of the Wheatland Unit, Laramie Division - Wyoming



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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE, REGION VIII
DENVER, COLORADO

DECEMBER 1963

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PUBLIC HEALTH ASPECTS
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WYOMING

Study of Effect of Project Development on Water Quality, Needs and Value of Water for the Purpose of Water Quality Control, and the Public Health Aspects of the Wheatland Unit, Laramie Division - Wyoming, Bureau of Reclamation, Region 7

Prepared at the Request of and in Cooperation
with the
Bureau of Reclamation, Region 7
U. S. DEPARTMENT OF INTERIOR
Denver, Colorado

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VIII
Division of Water Supply and Pollution Control
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I. INTRODUCTION

Authorization

The Department of Health, Education, and Welfare has the responsibilities assigned by the Water Pollution Control Act (Public Law 84-660), as amended by Public Law 87-88), concerning the inclusion of storage for regulation of streamflow for the purpose of water quality control. In a meeting March 19, 1963, between the Bureau of Reclamation, Region 7, Department of the Interior, and the Public Health Service, Region VIII, Department of Health, Education, and Welfare, and a subsequent letter of May 1, 1963 from the Bureau of Reclamation, the Public Health Service was requested to evaluate the effects upon water quality that would result from the development of the Wheatland Unit, and consider the need for and value of water storage for regulation of streamflow for the purpose of water quality control.

Purpose and Scope

General objectives of this study are to assess the probable effects of project construction and operation on water quality in local streams, reservoirs, and wells; to ascertain the benefits or harm resulting from changes in water quality; and to determine the need for and the value of storage for regulation of streamflow for the purpose of water quality control. These objectives were studied in the light of present conditions; also under anticipated economic development of the years 1985, 2010, and 2060.

The report also includes the results of a study of general public health aspects and insect vector control of the project. The insect vector control section, prepared jointly by the Wyoming State Department of Public Health, Cheyenne, Wyoming, and the Communicable Disease Center, Public Health Service, Greeley, Colorado, presents a preliminary evaluation of the insect vector problems that may be associated with development of the Wheatland Unit.

Acknowledgements

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Unit Office, Wheatland, Wyoming

Wyoming State Engineer's Office, Cheyenne,
Wyoming

PART A - WATER RESOURCES STUDY

II. SUMMARY AND CONCLUSIONS

Summary

1. The Wheatland Unit, Wyoming, is a proposed irrigation project of the Bureau of Reclamation. It provides for the replacement of the existing interception and storage facilities on the Laramie River, importation of water from the Medicine Bow River Basin, and increased pumping of ground water in the Wheatland Flats. The project area comprises about 55,000 acres, of which 46,390 acres will receive an additional 20,200 acre-feet of water. Of the additional 20,200 acre-feet, ground water would amount to 11,500 acre-feet and surface water, 8,700 acre-feet.

2. Practically the entire economy of the Wheatland Unit is agriculture and agriculturally oriented, especially when farm commodities manufacturing and farm products handling industries are included. Wheatland is the center of commercial activity in Platte County and is also the county seat.

3. Population in the Wheatland area has decreased from 4,500 people in 1930 to 3,900 in 1960. The downward trend in overall population is due to the out-migration of the younger people in the labor force, since the birth rate in the area is about three times the death rate. There is less opportunity for local employment at comparable wages than in other parts of the state and nation, resulting in under-employment of the human resources.

4. Surface water in the project area is used for irrigation. The Town of Wheatland and the individual farms in the area depend on ground water for their domestic water supply.

5. The surface water which is diverted to the Wheatland Flats for irrigation is of satisfactory quality for the irrigation of most crops. The quality of ground water varies somewhat with the depth and formation from which it is pumped. The concentration of dissolved solids in water from shallow wells averages about 650 milligrams per liter (mg/l) while the water from deep wells averages about 500 mg/l.

Conclusions

1. Agriculture and agriculturally oriented industries are expected to be the major industries in the Wheatland area. The future indicates a limited growth pattern on a fairly stable basis.

A large part of this growth will probably come as a part of the overall economic situation which is likely to result in higher basic income from outside sources.

2. If economic growth of the area is to occur, new industries, development of those now in existence, or generally promoting the area must take place. Development of ground waters and surface waters are essential for full economic growth.

3. Wheatland area's population is expected to increase from 3,900 in 1960 to 4,200 by the year 1985; 4,300 in 2010; and 4,300 in 2060. Because the area is almost entirely agricultural and agriculturally oriented the pattern of growth is limited to additional production and catering to travelers.

4. The pumping of ground water in the Wheatland Flats for irrigation is expected to result in a deterioration in the quality of the ground water. This deterioration is expected to be of greater magnitude with project development than without.

5. The resulting increase in the salinity of the irrigation water due to the deterioration of ground water quality is expected to have no definite adverse effects on crop production. However, there may be some isolated cases where adverse effects to crop production will result from the use of ground water for irrigation during dry years. No dollar value has been assigned to these adverse effects due to the uncertain nature of their occurrence.

6. Over the 100-year study period, it is anticipated that under project conditions the concentrations of sulfates, fluorides, and dissolved solids in the ground water will exceed the 1962 Public Health Service Drinking Water Standards. However, without the project only sulfates and dissolved solids are expected to exceed the standards. Total hardness will increase more with project development than without. With anticipated deterioration in quality of ground water supplies it may be necessary for the Town of Wheatland to seek a new source of water supply by 1985 with the project development, but not until 2010 or later without the project.

7. There will be an increase in the concentration of dissolved solids in the Laramie River downstream from the project area. The increase will be greater with the project than without, but is not expected to affect the medium salt-tolerant crops grown on the river bottom lands downstream from the project. This degradation in water quality is not expected to reflect any change in quality of the North Platte River; therefore, no monetary value has been assigned.

8. A minimum flow of three cubic feet per second (cfs) in the Laramie River at the Uva gaging station will be needed to assimilate the future treated wastes from Wheatland. It is anticipated that an additional 120 acre-feet of water will be needed annually to maintain this minimum flow. This supplemental flow will normally be needed during the months of July, August, September, and October.

9. The increased deterioration of the ground water due to project development will reflect in increased costs to the farmers and residents of the Wheatland Flats. Project development would necessitate the development of a new municipal water supply for Wheatland sooner than would be necessary without project development. If the cost of purchasing water is included, the increased costs to Wheatland would be about $10,000 per year. However, if Wheatland can trade ground water pumped from its wells for the water it will need, the increased costs would be reduced to about $9,000 per year. Increased hardness of the ground water will result in costs of about $1,000 per year to the rural residents of the Wheatland Flats.

The positive benefits of providing an additional 120 acre-feet of water annually for streamflow regulation would amount to about $2,000 annually. If the water is not provided for this purpose, no positive benefits can be considered.

III. DESCRIPTION OF PROJECT AND STUDY AREA

Proposed Project Development (1)

Project developments will affect parts of three counties in southeastern Wyoming: Platte, Albany, and Carbon. The proposed project developments along with the existing facilities are shown on Figure 1 (preceding the back cover). The Wheatland Irrigation District operates the existing facilities supplying surface water to the Wheatland area for irrigation. The facilities and their operation are as follows: Wheatland Reservoir No. 2, 100,000 acre-feet capacity, is used as the main storage reservoir; water released from this reservoir is diverted from the Laramie River via Wheatland Tunnel to Bluegrass Creek, which flows into Sybille Creek; the water is then conveyed to the farms by means of canals and laterals.

Ground water is used to supplement the surface supply, especially during dry years and late in the growing season. The drouth years of 1953 to 1956 resulted in an increased use of ground water for irrigation. Prior to that time there was only scattered development of ground water. The amount of water pumped for irrigation varies from year to year, with an estimated 3,300 acre-feet being pumped in 1959.

The proposed plan of development for the Wheatland Unit consists of importing water from Ringsby Ranch, building Dodge Canyon Dam and Reservoir, lining 22 miles of canal, and the development of ground water for the purpose of irrigation. The Wheatland Irrigation District acquired the water rights to Ringsby Ranch, which is located in the eastern part of Carbon County. It is anticipated that 7,100 acre-feet of water annually can be conveyed by means of canals from the Ringsby Ranch to the Laramie River above the existing Wheatland Reservoir No. 2.

The Dodge Canyon Dam and Reservoir will replace the existing Wheatland Reservoir No. 2. The new reservoir will have an active capacity of 250,000 acre-feet and permit storage of occasional Laramie River spills which are presently lost. The dam and reservoir are located in Albany County.

The Bureau of Reclamation proposes to line several miles of canals and laterals. This would result in an increased amount of water delivered to the farm headgates. The development of ground water will consist of drilling new wells and purchasing of the best existing wells to give a total of 53 deep wells. These wells would be pumped throughout the irrigation season to give an average annual yield of about 15,600 acre-feet. It is proposed to pump the ground water into laterals, where it will have a chance to mix with surface water before being applied to the land.

The Bureau of Reclamation anticipates that proposed development will permit an additional 20,200 acre-feet of water to be delivered to the farm headgates. The project area consists of about 55,000 acres, of which 50,455 acres have been classified as Classes 1, 2, 3, and 6W by the Bureau of Reclamation. The 4,065 acres that have been classified 6W land will not receive additional water, the remaining 46,390 acres will receive a supplemental supply.

Description of Study Area

Boundaries

For purposes of this study, Platte County was considered as the area mostly affected by project development. More specifically, the town of Wheatland and the surrounding farming area would be directly affected.

Location

The Wheatland Unit is located in southeastern Wyoming. Most of the suitable irrigable lands of the project are located in the Wheatland Flats, which is the area surrounding Wheatland, Wyoming. The Wheatland Flats are bounded by the Laramie River on the north, Sybille Creek on the west, and Chugwater Creek on the east. The Laramie River is the major source of surface water in the project area.

Topography (1)

The surface relief of the project area varies from mountainous terrain to that of the high plains. The Wheatland Flats lie on four major terraces that rise up to 200 feet above the steams forming its boundaries. These four terraces range in elevation from 4,600 to 5,300 feet above mean sea level and are oriented roughly parallel to the Laramie River and Sybille Creek. Surface slopes on the individual terraces generally exceed 20 feet per mile.

Soils (1)

Soils on the irrigated sections range in texture from fine sandy loam to sandy clay loams underlain by sand, gravel, or cobble. Most of the soils are derived from Pleistocene sands or gravels. There are no extensive silt or clay layers that would impede subsurface drainage.

Salinity and Alkalinity

Some scattered areas of salt or alkali accumulations are found on the project lands. These accumulations are a result of restricted drainage and are found mainly around the western and northern periphery of the Wheatland Flats.

Drainage (1)

Drainage and surface water disposal problems on the Wheatland Project have not been extensive. Surface drainage from the Wheatland Flats is largely disposed of through the natural channels. There are 24 known systems constructed for farm drainage and include approximately 12 miles of tile drain and 7 miles of open drain. There are some marshy areas caused by high water tables and poor drainage. These spots of poor drainage are caused by the surface configuration of the Arikaree formation, which is a fine grained sandstone. Normally, the Pleistocene deposits of sands and gravels provide ready passage for farm losses and excesses.

Climate (1)

The Wheatland Unit has a semi-arid type climate which is typical of the high plains. Precipitation averages only about 13 inches per year at Wheatland, Wyoming, with the months of April and May receiving the greatest precipitation. Experience has shown that most farm crops cannot be grown successfully without irrigation. The extremes in temperatures recorded at the Wheatland weather station are minus 36°F and 109°F.

Transportation, Communications, and other Facilities

U. S. Interstate Highway 25, and U. S. Highway 87 traverse the project area, while U. S. Highway 26 bounds the project area on the north. The Colorado and Southern Railroad provides rail transportation for the area. The town of Wheatland has a municipal airport which is used for private air transportation.

The Mountain States Telephone and Telegraph Company supplies communication service to the Wheatland area. There is a grade school and a high school in Wheatland. The University of Wyoming is located at Laramie, Wyoming, about 80 miles to the southwest.

IV. THE ECONOMY

Resource Base

The Wheatland Unit and Platte County is one of the few, almost entirely agricultural areas in the State of Wyoming. Water for irrigation comes primarily from the Laramie River and a low priority of rights makes for problems in dry years. In years of prolonged drought the farmers near Wheatland have found and may find themselves practically without irrigation water unless a more firm supply is planned and developed. The building of the Wheatland project was commended in 1883 with the first irrigation being carried out that year. The Wyoming Development Company continued the development of Wheatland Flats under the Carey Act of 1894. This company bought and sold deeded land with water rights.

Agriculture is by far the most important source of personal income. It would be even more so if the manufacturing and farm product handling industries were included, as agriculturally oriented. These include exports of agricultural products by farmers and ranchers, exports of agricultural products by handlers of such products, and exports of manufactured products consisting of processed agricultural commodities. Together they represented more than 50 percent of the labor force and basic income in 1959.(2)

In Platte County gross cash income from sale of cattle and calves amounted to 64 percent of the total income in 1959.(2) Two types of operation are involved, ranch production of feeder cattle and to a lesser degree, farm fattening operations. An assured feed supply is necessary for extensive feeding operations. Under present conditions, Platte County farmers do not have this assurance for any particular year because an adequate water supply is not always available.

Markets for agricultural products are located largely to the east of the Wheatland area. Livestock move into the corn belt for fattening. Cash crops also move to the eastward. Local markets consist of: farmers and ranchers who purchase livestock, hay and grain, machine use, and many other things from one another; manufacturers who purchase livestock for further processing; and handlers of farm products who purchase such crops as field beans and do limited processing such as cleaning, sorting, grading, and packaging for export. Handlers of farm products also import such things as feeds, fertilizers, insecticides and herbicides which they sell to local farmers and ranchers.

(3) Manufacturing in Platte County is limited to nondurable goods. Manufacturing comprised only one percent of total employment in 1960, with food and kindred products accounting for 0.6 percent and printing and publishing the remaining 0.4 percent. Crops, livestock, and dairy products were the principal items processed. Generally speaking, employment in manufacturing changes very little from year to year in this area, but it lends considerable stability to the overall economy.

(2) Platte County is one of the few areas in Wyoming where oil and natural gas do not make a major contribution to the economy. The only major mineral development is iron ore produced at Sunrise, and is owned by the Colorado Fuel and Iron Corporation of Pueblo, Colorado. This is one of the more important iron mines west of the Mississippi River. Current iron ore production, about 600,000 tons per year, provides year-round employment for 228 men, or about nine percent of the county labor force. Employment is a fairly sensitive indicator of production as well as the contribution of this industry to the local economy. The mine is electrified and modern techniques are used. Ore presently mined in the Sunrise Mine is predominantly hematite, limonite, and geothite. Various assays range from 55 to 68 percent iron content.

(3) Construction activity varies considerably from year to year in Platte County. In 1960, about nine percent of the labor force was employed in construction. About five percent was employed in building state and federal highways.

(3) Rail, truck, and other transportation employed about six percent of the labor force in Platte County in 1960. The Colorado and Southern Railroad (a subsidiary of Burlington) serves most of Platte County. U. S. Highway 87 (soon to be Interstate 25) runs north and south through the county and U. S. Highway 26 runs east and west.

(2) About one percent of the nights spent in Wyoming by out of state travelers is spent in Platte County. Wheatland, being the largest town and county seat, receives most of this trade. Travel expenditures are not a big factor in the economy but could become much larger when Interstate Highway 25 is completed. Glendo and Guernsey Reservoirs are attractive for fishing and boating and grainfields of the Wheatland area make excellent pheasant hunting.

(3) Educational services and public administration comprised about 13 percent of the labor force in Platte County in 1960, while other services accounted for the remaining 12 percent. These services are population-oriented.

Present and Past Population

(4) As is true nationwide, agriculturally oriented communities tend to lose population. This has been true in the Wheatland area which has decreased from about 4,500 people in 1930 to 3,900 in 1960. The town of Wheatland has grown from about 2,000 to 2,500 over the same period, while the rural area has decreased from about 2,500 to 1,500. People have moved from the farms to Wheatland with highway improvement and greater mobilization.

The downward trend in overall population is due to outward migration, since the birth rate in the area is about three times the death rate. The heaviest out-migration has occurred among the younger members of the labor force, because there is less opportunity for local employment at comparable wages than in other parts of the state and nation. The area is under-employed because the human resources are not being fully utilized. New job opportunities must be provided if the trend is to change. Also, the area may become fairly heavily dependent upon social security payments and other sources of retirement income unless more intensive local activity or additional processing plants are introduced.

Future Growth

Since this area is heavily dependent upon agriculture and agriculturally oriented industries, trends shown by that industry are extremely important, both in assessing the present and in projecting for the future. The future indicates a limited growth pattern on a fairly steady basis. A large part of this growth will probably come as a part of the overall economic situation which is likely to result in higher basic income from outside sources. This basic income represents payments made by persons residing outside the Wheatland area for goods and services produced inside it.

(2) Each dollar of new money introduced into the economy through shipment of agricultural commodities by farmers in 1959 produced $1.97 of additional income by circulating through the economy. Handlers of farm products also shipped commodities out, and each dollar's worth was responsible for $1.89 of additional income. Manufactured agricultural exports had an income generating power of $1.62. Each dollar of minerals produced was worth $1.36 to the community. Each dollar spent by travelers created another dollar of income. Other income had a generating power of $1.29. Overall, the income generating power of each basic dollar was $1.63.

Agriculture will likely continue to be the major industry in this area. The trend toward larger and fewer farms with relatively larger investment in labor-saving machinery and equipment is expected to continue. This would be partially offset by the proposed Wheatland project. The additional water would provide an adequate supply and would have a tendency to reduce farm size, because fewer acres would be required to support a family than presently.

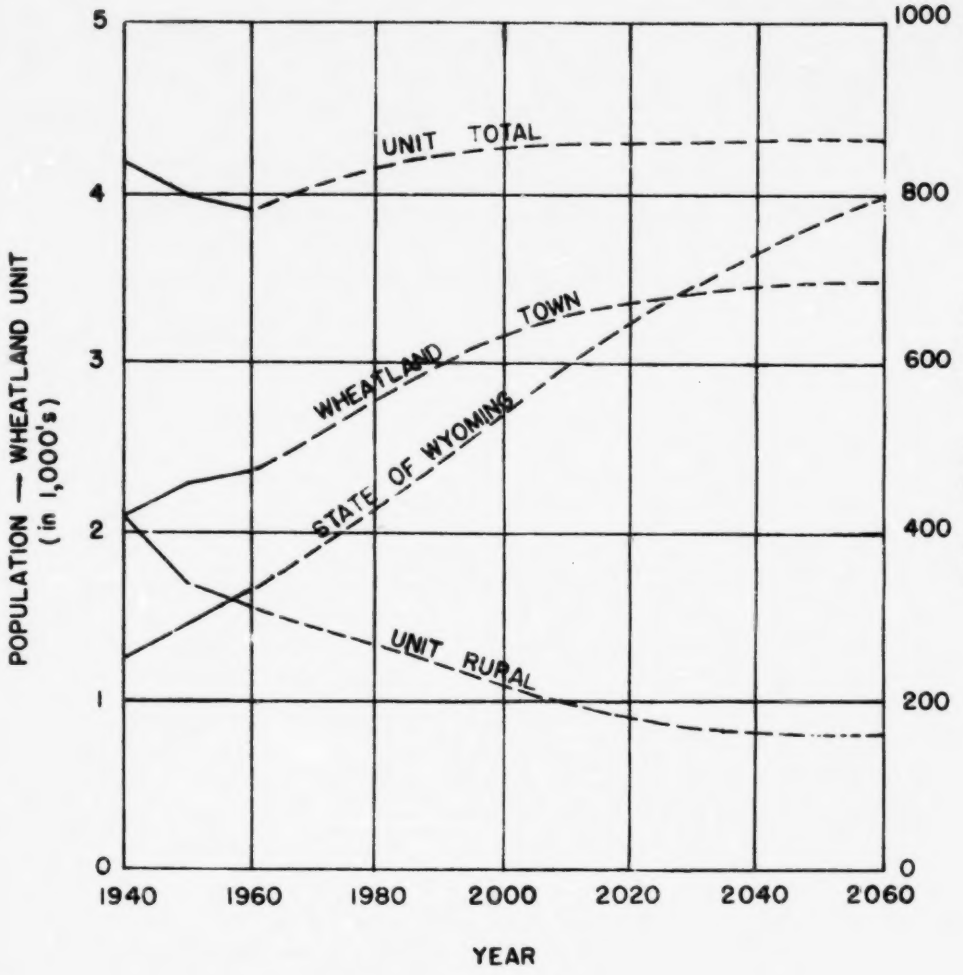
Manufacturing in this area is largely the processing of agricultural products. It is expected to increase with development of the Wheatland project, but the amount of local market is not expected to increase greatly.

(2) The iron ore mines in Platte County are now underground and are captive. This means that the economy from iron ore will be tied closely to the fortunes of the Colorado Fuel and Iron Corporation. It costs about four times as much to mine from underground pits as from surface pits, thus iron ore would have to be in considerable demand in the future for iron ore mining in Platte County to be competitive. However, cost of shipping would give Colorado Fuel and Iron an advantage in the open markets of Colorado, New Mexico, Wyoming, western Kansas, and western Nebraska because of the close proximity and the relatively low cost of shipping from Sunrise.

Interstate Highway 25 is expected to be completed by 1970, after which construction funds will contribute much less to the economy. Likewise, the amount paid out to highway employees for operation, maintenance and repair will be reduced.

With completion of the interstate system through Platte County, traffic through the Wheatland area will be increased, but expenditures will not increase proportionately because of higher speeds, hence less time spent in the area. Promotional efforts could induce travelers to spend more time in the area and result in additional dollars being spent, especially with service firms. These firms have a higher income generating power than retail firms. Luring travelers to the area is one of the best prospects for improving the local economy in the future.

People are always the best resource of any area. Unless some drastic change takes place, opportunities for young people will continue to be scarce. This could be changed by introduction of new industries, further development of those now in existence, and general promotion of the area. Construction of the Wheatland project should give the area an immediate boost during construction, with considerable carryover effects. Even with development of the project the rural area is expected to decrease in population. The town of Wheatland will probably continue its limited growth pattern on a fairly steady basis due to an increase in service firms. Projected population for Wyoming, Wheatland, and the rural areas surrounding Wheatland are shown in Figure 2.



WHEATLAND UNIT
WYOMING

POPULATION

DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO

12-B

FIGURE 2

V. WATER SUPPLY

Uses

The Laramie River and its tributaries upstream from the Wheatland Flats have provided an average annual flow of 87,800 acre-feet of water into Wheatland Reservoir No. 2 over a 32-year period (1928-1959).[1] In addition, it is expected that an average of 7,100 acre-feet of water annually can be imported to the reservoir from the Ringsby Ranch.[1] This water will be diverted to the Wheatland Flats to be used for irrigation. The Laramie River downstream from Wheatland Reservoir No. 2 is not used as a source of municipal water supply.

The runoff from Sybille Creek above Bluegrass Creek averaged about 13,000 acre-feet annually for the above 32-year period.[1] This flow can be diverted for irrigation or storage in Wheatland Reservoir No. 1.

Ground water is used for domestic and municipal water supply, stock watering, and irrigation. The amount of water pumped for irrigation has varied from year to year, with 3,300 acre-feet being pumped in the Wheatland Flats during 1959.[1] An inventory of ground water development in 1959 and 1960 indicated that approximately 275 wells in the project area were used for domestic and stock water supply.[1] The current level of ground water pumping for municipal, domestic, and stock water supply has been estimated by the Bureau of Reclamation to be about 500 acre-feet per year. It is anticipated that in the future about 1,000 acre-feet per year will be pumped for these purposes.[1]

Water Quality

Mineral

The available water quality data of streams affected by the project are summarized in Table I. The data for Wheatland Canals 1, 2, and 3 represent the quality of the surface water diverted to the Wheatland Flats for use in irrigation. This water is of acceptable quality for irrigation of most crops and all those presently grown on the Wheatland Flats. In general, mineral quality is within the 1962 Public Health Service Drinking Water Standards.[5] The only exception is the concentration of dissolved solids, which occasionally exceeds the standards.

TABLE I

Mineral Analyses of Streams[1/]

Location and Period	Ec[2/]	pH	TDS	Ca	Mg	Na	HCO_3	SO_4	Cl	F	Hardness
			Milligrams per Liter								
Wheatland	756	7.8	515	72	30	45	186	217	16.0	0.5	302
Canal #1	594	7.2	391	57	20	32	159	147	8.4	0.4	240
1958-1959	632	--	419	61	24	36	171	168	11.2	0.4	253
Wheatland	926	8.0	648	100	36	56	234	243	18	0.8	398
Canal #2	658	7.4	437	67	25	37	204	157	12	0.5	269
1958-1959	705	--	474	72	27	72	214	180	13	0.6	291
Wheatland	811	7.8	549	93	29	44	240	196	25	0.6	352
Canal #3	581	7.5	372	64	20	26	266	95	11	0.5	257
1958-1959	653	--	425	73	25	32	257	125	14	0.6	287
Chugwater Creek	913	8.5	642	107	42	70	328	204	21	0.8	376
near Uva, Wyo.	764	7.4	527	63	23	54	223	187	17	0.6	267
1958-1959	881	--	614	92	29	62	306	195	19	0.6	348
Laramie River	957	8.2	658	110	60	68	256	235	24	0.8	408
near Uva, Wyo.	458	7.3	308	29	13	26	164	73	9	0.4	184
1956-1959	695	--	474	71	24	44	250	144	15	0.6	276

1/ Data from Geological Survey Water Supply Papers 1521 and 1572 and unpublished data; 1st line entry maximum concentration; 2nd line entry minimum concentration; 3rd line entry flow weighted mean concentration

2/ Electrical conductivity in micromhos per centimeter

The higher concentrations of salts in the waters of Chugwater Creek near its mouth reflect the influence of irrigation return flows. The flow of the Laramie River near Uva, Wyoming, consists of irrigation return flows from the Wheatland Flats, undiverted flow of the Laramie River, and the flow from the north Laramie River. The latter has a diluting effect, resulting in an annual weighted average concentration of dissolved solids in the Laramie River near Uva of 474 mg/l. During the periods of low flow the affect of the irrigation return flows is more pronounced, resulting in higher concentrations of dissolved solids, 658 mg/l, during these periods.

The quality of ground water in the Wheatland Flats varies somewhat with the depth and the geologic formation from which the water is pumped. The variation in mineral quality of ground water samples collected from 1953 to 1963 is shown in Table II. Figure 3 shows the location of the sampling points. Most of the shallow wells in the area draw their water from the terrace gravels, which range from zero to 80 feet in thickness. The concentration of dissolved solids in water from these wells averages about 650 mg/l. The deep wells in the area extend into the Arikaree formation, which is a fine sandstone underlying the terrace gravels. The water from the deep wells is generally of better quality, with the concentration of dissolved solids averaging about 500 mg/l. Some of the deep wells yield water having concentrations of iron as high as 3.8 mg/l. Although the concentrations of dissolved solids and iron exceed the 1962 Public Health Service Drinking Water Standards, the water from deep wells is generally acceptable for domestic use.

Sanitary

There are very few sources of organic pollution along the Laramie River. Laramie (20,670), Wheatland (2,350), and Fort Laramie (250), are the only towns of any size along the river. Laramie is approximately 100 miles upstream from Wheatland, while Fort Laramie is about 30 miles downstream from Wheatland. All three of these towns use waste stabilization lagoons to treat their waste water. The Wyoming State Department of Public Health reports no organic pollution problem affecting water quality of the Laramie River at this time.

State Standards

The State of Wyoming does not have a stream classification system. The drinking water standards of Wyoming apply only to the bacteriological quality of the water. These standards are the same as the bacteriological section of the 1962 Public Health Service Drinking Water Standards.

TABLE II

Chemical Quality of Ground Water in the Wheatland Flats

Well Number 1/	Well Depth (feet)	Collection Date 2/	pH	Ec	Fe	Ca	Mg	Na	HCO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness
					Milligrams per Liter											
1	500	8-21-53	7.7	660	0.04	74	23	27	186	139	22	0.6	12	0.08	496	280
		6- 4-63	7.6	690		86	29	28	220	115	39				500	337
2	500	10-31-55	7.8	507		56	18	23	186	73	16	0.6	13		373	214
		6- 4-63	7.3	610		76	29	22	201	109	34				450	313
3	630	10-27-59	7.1	721	1.20	91	26	25	256	156	12	0.5	4	0.03	522	334
		6- 4-63	7.5	770		101	35	25	226	175	21				560	397
4	150	8-19-53	7.7	807	0.27	91	33	32	263	172	16	1.4	19	0.09	604	362
		6- 4-63	7.6	850		110	35	32	268	189	21				620	419
5	512	6- 4-63	7.6	650		91	29	15	220	151	34				470	348
6	265	9-30-59	7.1	648	0.02	79	20	26	231	124	15	0.6	7	0.05	462	280
		6- 4-63	7.7	500		69	17	23	207	68	34				365	244
7	508	6- 4-63	7.6	710		106	28	23	220	154	41				538	379
8	567	6- 5-63	7.6	600		81	35	21	195	130	31				492	346
9	500	6- 5-63	7.6	420		53	19	16	171	39	31				305	213
10	500	6- 5-63	7.8	500		62	20	26	171	81	32				360	237
11	450	6- 5-63	7.6	480		64	17	19	220	67	39				350	231
12	95	6- 5-63	7.8	770		88	28	60	317	138	18				544	337
13	320	6- 5-63	7.6	820		102	28	63	281	180	27				580	370
14	300	6- 5-63	7.6	920		104	51	48	311	226	45				668	475
15	300	6- 5-63	7.7	750		71	40	47	268	143	41				545	342
16	70	10- 8-59	7.8	803	1.70	83	32	47	269	188	13	0.5	12	0.11	570	338
		6- 5-63	7.6	800		88	36	46	317	156	41				580	368
17	24	8-18-53	7.9	927	0.07	66	56	55	305	228	15	0.7	8	0.16	622	395
		6- 5-63	7.6	1050		98	69	62	287	282	46				728	532
18	43	6- 6-63	7.5	950		95	47	62	275	223	53				690	430
19	38	6- 6-63	7.6	1030		103	55	71	317	241	76				752	486
20	530	6- 6-63	7.5	1020		113	42	72	275	262	62				716	457
21	500	6- 6-63	7.6	560		75	25	20	183	100	55				410	291
22	500	6- 6-63	7.6	590		90	30	20	214	134	71				500	351
23	500	6- 6-63	7.6	600		72	21	37	214	120	43				435	268
24	500	6- 6-63	7.6	720		95	30	19	153	191	57				520	362
25	43	8- 9-53	7.7	948	0.05	96	42	52	327	204	14	0.6	28	0.20	668	414
26	52	8-18-53	7.5	902	0.03	89	44	48	332	189	12	0.6	16	0.14	606	402
27	27	8-18-53	7.8	774	0.02	72	35	44	267	167	13	0.8	12	0.09	506	325
28	28	8-19-53	7.6	1010	0.[illegible]	100	46	62	340	245	16	0.9	14	0.13	698	438
29	21	8-19-53	7.7	1140	0.11	98	58	75	401	280	19	1.2	2	0.18	786	484
30	250	10-27-59	7.0	421	0.33	42	18	19	182	42	14	0.7	7	0.13	269	178
31	635	10-27-59	7.1	696	0.90	86	25	22	214	148	20	0.7	10	0.08	509	318
32	215	10-17-59	7.0	704	3.80	85	27	19	175	169	27	0.4	11	0.05	517	324

1/ Well locations are shown in Figure 3 by well number

2/ Samples collected before June 1963 were collected and analyzed by USGS.
Those samples collected during June 1963 were collected by the Public Health Service and were analyzed by the Bureau of Reclamation.

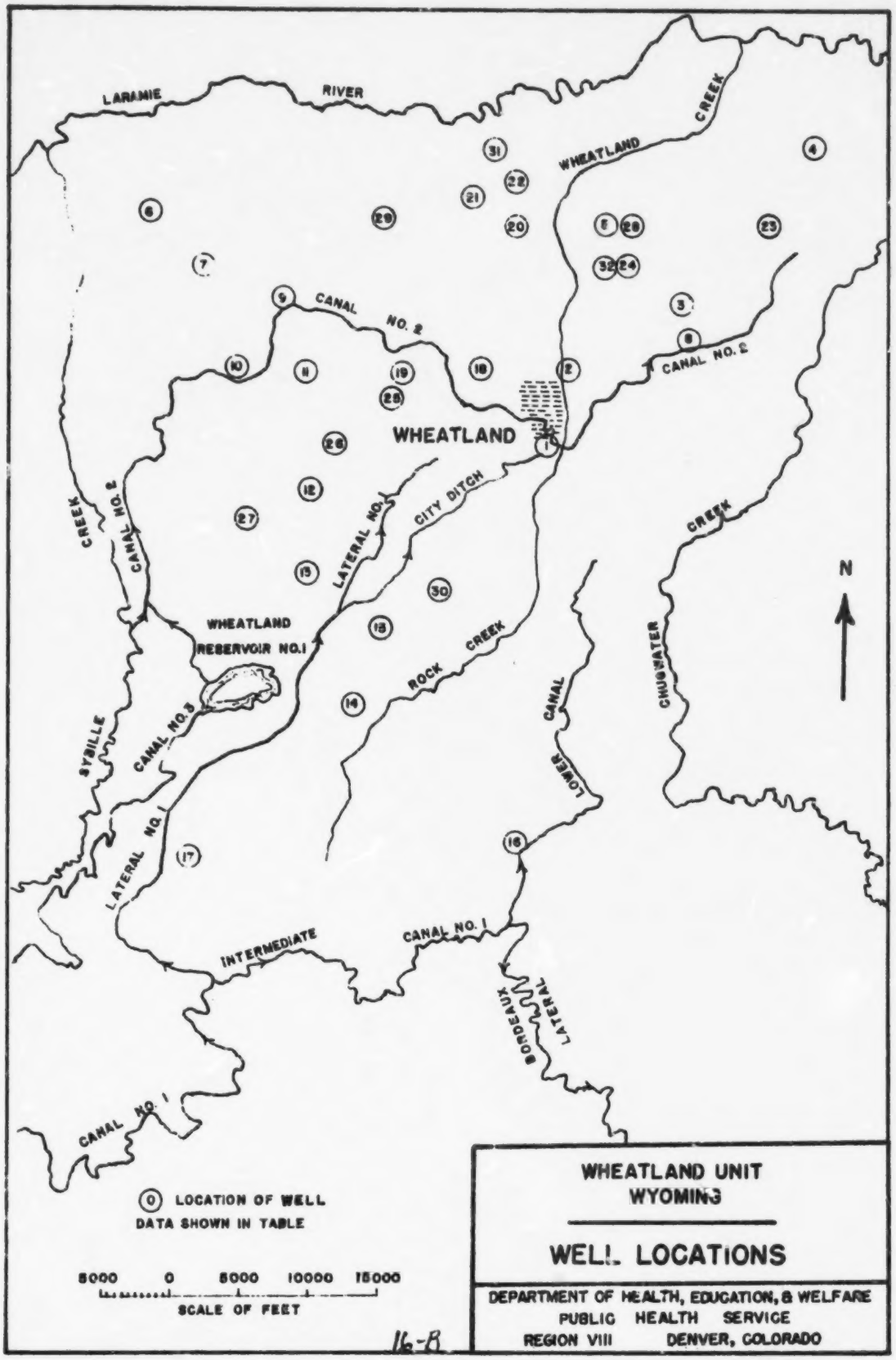

LARAMIE RIVER
WHEATLAND CREEK
CANAL NO. 2
WHEATLAND
CITY DITCH
LATERAL NO.
CREEK
CANAL NO. 2
WHEATLAND RESERVOIR NO. 1
ROCK CREEK
LOWER CANAL
CHUGWATER CREEK
SYBILLE CREEK
CANAL NO. 3
LATERAL NO. 1
INTERMEDIATE CANAL NO. 1
BORDEAUX LATERAL
CANAL NO. 1
N
(0) LOCATION OF WELL DATA SHOWN IN TABLE
5000 0 5000 10000 15000
SCALE OF FEET
16-B
WHEATLAND UNIT
WYOMING
WELL LOCATIONS
DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO

FIGURE 3

VI. EFFECTS OF PROJECT OPERATION

Ground Water Deterioration

It is expected that the pumping of ground water for irrigation purposes will result in a gradual deterioration of ground water quality in the Wheatland Flats. This expected increase in the concentration of dissolved solids will be due to the reuse of ground water for irrigation. The increased pumping of ground water causes a decrease in the outflow from the ground water basin, which results in an increase in the concentration of dissolved solids. The Bureau of Reclamation has made the only known comprehensive study in the project area for the purpose of predicting the future change in ground water quality.(1) The mathematical formula derived by the Bureau and the assumptions used in derivation are shown in Appendix A.

Although the Bureau of Reclamation used a depth of mixing of 100 feet in making calculations of future ground water quality, they consider this depth to represent conditions which would exist during a period of prolonged drought. Based on the average depth of the 53 wells and the anticipated drawdown of these wells, a depth of mixing of 150 feet is considered by the Public Health Service to be more representative of conditions that will occur. In this study, future ground water quality was computed using the Bureau's equation, a depth of mixing of 150 feet, and an initial dissolved solids concentrations of 500 mg/l. The anticipated concentrations of dissolved solids, mg/l, in the ground water without and with project development are summarized in Table III.

TABLE III

Anticipated Concentrations of Dissolved Solids in Ground Water

Year	Without Project	With Project
1960	500	500
1985	725	925
2010	900	1275
2035	1025	1550
2060	1100	1775

Irrigation

In calculating the quality of irrigation water it was assumed that the surface water and ground water would be uniformly mixed at the farm headgates. The anticipated electrical conductivity of the irrigation water, without and with project development, is given in Table IV. The quality of an irrigation water depends upon the kind and amount of salts dissolved in it. Generally the quality problems are caused by excessive concentrations of sodium ions, boron ions, and/or high concentrations of dissolved solids. The anticipated concentrations of sodium and boron ions in the irrigation water are less than 50 and 0.5 mg/l, respectively. According to Agriculture Handbook No. 60,[6] these concentrations are well within the upper limits for use in irrigation.

TABLE IV

Anticipated Electrical Conductivity of Irrigation Waters

Year	Without Project	With Project
1960	700	700
1985	715	800
2010	730	885
2035	735	950
2060	740	1005

The salt tolerance of plants varies from species to species, with field beans being one of the most salt sensitive crops. A small loss in the yield of field beans may be expected when the electrical conductivity of the saturation extracts of the soil reaches 2,000 micromhos per centimeter.[7] The salts left in a soil solution by evapotranspiration must be removed by leaching to prevent a build-up to harmful concentrations. The theoretical amount of water required to maintain equilibrium salt concentration in the soil solution is a function of the mineral content of the applied water.

The Bureau of Reclamation made a detailed study of the leaching requirements for the Wheatland Project. The results of the study were transmitted to the Public Health Service via a letter dated September 5, 1963. The conclusion of this study was that at the end of the 100-year study period the leaching requirements for the mixed irrigation water would amount to 29 percent of the applied irrigation water. In the hydrology study of the Wheatland Project the Bureau of Reclamation has estimated that annually 32 percent of the applied irrigation water would go to deep percolation. Additional studies made by the Public Health Service indicate that the 32 percent deep percolation would be adequate to meet the leaching requirements of the mixed irrigation water.

Based on the anticipated ground water deterioration and the proposed operations plan for the Wheatland Project, the quality of the mixed irrigation water will be satisfactory for irrigation of present and anticipated crops.

Municipal and Domestic Water Supply

In making the calculations of future ground water quality, it was assumed that the relative proportions of the chemical constituents would remain constant as the concentration of dissolved solids increased. Over the 100-year study period, it is anticipated that under project conditions the concentrations of sulfates, fluorides, and dissolved solids will exceed the limits of the 1962 Public Health Service Drinking Water Standards. However, without the project, only sulfates and dissolved solids will exceed the standards. Total hardness will increase under both conditions. The anticipated concentrations, mg/l, of these chemical constituents are summarized in Table V.

TABLE V

Anticipated Mineral Quality of Ground Water

	Without Project				With Project			
Year	F	SO_4	Hardness	Dissolved Solids	F	SO_4	Hardness	Dissolved Solids
1960	0.7	140	300	500	0.7	140	300	500
1985	1.0	205	435	725	1.3	265	555	925
2010	1.3	255	540	900	1.8	360	765	1275
2035	1.4	290	615	1025	2.2	440	930	1550
2060	1.5	310	660	1100	2.5	505	1065	1775

The Wyoming State Department of Public Health mentioned in a letter of July 8, 1963, to the Public Health Service that: "The predicted chemical quality of the ground water would indicate that Wheatland will undoubtedly seek a new source of water in approximately 25 years with the project operating. However, without the project it may not be necessary to develop a new source of water for something in the range of 50 to 75 years."

With the gradual deterioration of the ground water quality, most of the people in Wheatland would become physiologically acclimatized to the increasing concentration of salts. However, if the people of Wheatland did not want to consume the degraded ground water, the town could either use a desalinization process to treat the ground water, or develop a new source of supply.

Laramie River Downstream from Project

Most of the irrigation return flows to the Laramie River and its tributaries in the project area are attributed to ground water seepage. The Bureau of Reclamation anticipates that under future conditions without project development, the average annual flow of the Laramie River at the USGS gaging station near Uva, Wyoming, will be 80,500 acre-feet. With project development the flow is the anticipated to be 66,900 acre-feet. The expected deterioration of ground water will have an adverse effect on the quality of the water in the Laramie River below the project area. The anticipated average annual concentration of dissolved solids, mg/l, is shown in Table VI.

TABLE VI

Anticipated Annual Average Concentration of Dissolved Solids in Laramie River Uva Gaging Station

Year	Without Project	With Project
1960	480	480
1985	550	575
2010	600	650
2035	650	700
2060	675	750

During periods of drought it is estimated that ground water seepage will constitute a large percent of the Laramie River flow, resulting in the concentration of dissolved solids approaching that of the Ground water.

River bottom lands along the Laramie River from Uva gaging station to the confluence of the North Platte River are used for growing small grains, alfalfa, and meadow hay. Based on the limited data available and the expected economic growth of this area, no need is foreseen to improve or maintain mineral quality of surface waters. The quality of the North Platte River below its confluence with the Laramie River is expected to be about the same without, or with, project development.

Streamflow Regulation

Flow regulation of the Laramie River for assimilation of adequately treated waste from Wheatland would be beneficial in helping to maintain the aesthetic appearance of the stream and the limited fishing available downstream from Wheatland. In calculating the minimum desired flow for the assimilation of the wastewater, the following parameters were used:

1. A sewered population of 3500.
2. The untreated waste would have a biochemical oxygen demand (BOD) of 0.25 pounds of BOD per capita per day.
3. Waste treatment would be 85 percent efficient.
4. Maintain a dissolved oxygen content of at least 4 mg/l in the receiving stream.
5. Stream self-purification coefficients were chosen by analogy and judgment.

Based on these parameters it was calculated that a minimum flow of 3 cfs would be needed in the Laramie River downstream from Wheatland.

The USGS streamflow records show that the flow in the Laramie River, near Uva, Wyoming, (about 10 miles downstream from the project area) is less than 3 cfs about six percent of the time. The minimum daily streamflow on record at this point is 0.3 cfs. Based on these records it is anticipated that an additional 120 acre-feet of water annually will be needed to maintain a minimum flow of 3 cfs in the Laramie River near Uva, Wyoming. This supplemental flow will normally be needed during the months of July, August, September, and October. The need for streamflow regulation for the purpose of water quality control is expected to be about the same without project development as with project development.

VII. ECONOMIC BENEFITS

Both positive benefits and adverse effects due to project development were considered in determining economic benefits. The adverse effects were computed on the basis of increased costs to the farmers and residents of the Wheatland Flats. These increased costs are the differences between costs that would exist without and with project development. In the calculation of economic benefits, all values were discounted to present value, then amortized over a 100-year period.

Irrigation

Based on the results of the studies of the leaching requirements and the estimated 32 percent deep percolation of applied irrigation water, no definite adverse effects to crop production due to the anticipated increase in the concentration of dissolved solids are foreseen. However, during years of below normal precipitation there may be some farms in the Wheatland Flats that will have to use ground water as their only supply of irrigation water. The ground water will be substantially more saline than the mixed irrigation water, therefore, additional water would be needed for leaching purposes. As the ground water becomes more saline, the possible use of sprinklers for irrigation will become less desirable because of the added costs of pumping additional water for leaching purposes. Due to the uncertain nature of their occurrence, no dollar value has been assigned to these adverse effects.

Streamflow Regulation

Flow regulation of the Laramie River for assimilation of adequately treated waste from Wheatland would be beneficial in helping to maintain the aesthetic appearance of the stream and the limited fishing available downstream from Wheatland. The Fort Laramie National Monument, located on the Laramie River near its confluence with the North Platte River, had about 50,000 visitors in 1961. A clean stream is always an asset in attracting visitors and will add to the recreational value of the area. Based on the streamflow records it is estimated that on the average, an additional 120 acre-feet of water annually will be needed to maintain a minimum flow of 3 cfs in the Laramie River at the Uva gaging station. The positive benefits to be derived from this streamflow regulation are considered to be equal to the costs of providing water. The use of ground water appears to be the most economical method of providing water for this purpose. The costs of providing this water are estimated to be about $2,000 per year over the 100-year study period. These benefits are considered widespread in scope and hence non-reimbursable.

The 2,000 acres of irrigated land along the Laramie River from Uva gaging station to the North Platte River produce medium salt-tolerant crops which are not expected to be noticeably affected by project development. Therefore, no need is foreseen for streamflow regulation to maintain mineral quality.

Municipal Water Supply

For the purposes of this study it was assumed that with project development Wheatland will seek a new source of municipal water supply by 1985, whereas, without project development a new water supply will not be needed until 2010. These are the approximate years that the concentration of sulfates in the ground water supply is anticipated to exceed the 1962 Public Health Service Drinking Water Standards. The possible use of other water supplies and other methods of obtaining a suitable water supply were studied. Based on this study it was concluded that the surface water diverted to the Wheatland Flats for irrigation would be the most economical alternative as a new municipal water supply for Wheatland.

A water treatment plant would be needed to treat the water before it could be used for domestic purposes. An estimate of the costs of a transmission pipeline, water treatment plant, operating costs, and water rights was made. All yearly costs for both with and without project conditions were discounted to 1960 values. The difference in costs between with and without project conditions was then determined and amortized over the 100-year study period at three percent interest. Having to develop a new water supply in 1985 instead of 2010 would result in additional costs of about $10,000 per year to Wheatland.

There is the possibility that Wheatland might be able to trade ground water pumped from its wells for the surface water it will need for its municipal supply. This would reduce the costs of obtaining surface water and therefore reduce the difference in the costs from $10,000 per year to about $9,000 per year.

With development of the project, an increase in hardness would result in increased use of soap, detergents, and general household cleaners. Using a computed value of $1.15 per capita per year per 100 mg/l change in hardness,[8] the adverse effect to the domestic water supply of the farms in Wheatland Flats would be about $1,000 annually. The effect of hardness on the residents of Wheatland is considered in the increased cost for a new source of municipal supply.

The increased costs due to project development and the benefits for streamflow regulation are summarized below:

Increased annual costs to Wheatland if town must purchase surface water	$10,000/year
Increased annual costs to Wheatland if town can trade ground water for surface water	$ 9,000/year
Increased annual costs to farm residents in Wheatland Flats due to increased hardness	$ 1,000/year
Annual benefit for providing an additional 120 acre-feet annually for streamflow regulation	$ 2,000/year

PART B - PUBLIC HEALTH ASPECTS

I. SUMMARY AND RECOMMENDATIONS

Summary

Mosquitoes are the principal vectors which might be affected by the proposed project. Several species of mosquitoes of public health importance may be produced in the area when suitable aquatic habitats are present. Encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States and the area in which the proposed project is located. During 11 years of the 17-year period, 1939-1955, equine encephalitis cases occurred in Platte and/or Albany County. Although no outbreaks of human encephalitis have been recorded in these counties, the records of equine encephalitis cases indicate that the virus of encephalitis is active in the general area of the proposed project.

Recommendations

Overall watershed management requires the cooperation of many interests to assure that development and activities will minimize the potential public health hazards. It is recommended that the following be given due consideration in development of the Wheatland Unit, Wyoming:

1. That the water user's organization (i. e., Water Conservancy District) operating as the general administrative and contracting agency for the project should:

    a. Alert all water users of the potential public health hazards associated with using inadequately treated canal water for culinary purposes.

    b. Exert all possible precaution to exclude sewage effluents and barnyard drainage from project canals, laterals, and drains;

    c. Wherever and whenever possible assist the project inhabitants and communities in development of approved water and sewerage facilities;

    d. Operate and maintain project facilities in accordance with established criteria.

2. That potential recreational areas be investigated and at least minimum water and sanitary facilities be provided in accordance with Wyoming State Department of Public Health.

3. That a sanitary survey of proposed construction campsites be made and all camps be provided with water and sanitary facilities in accordance with Wyoming State Department of Public Health regulations.

4. That recreational activities at reservoirs utilized as a source of public water supplies meet the requirements established by the Wyoming State Department of Public Health.

5. That person or persons responsible for a public water supply establish suitable controls over the use of watershed areas tributary to the supply to insure production of raw water meeting the quality requirements established by the Wyoming State Department of Public Health.

6. That all efforts be extended during construction stages, including land leveling and clearing, to exclude excess silt and debris from all water courses.

7. That the Wyoming State Department of Public Health be kept currently informed regarding changes in plans and proposed construction schedules so that guidance and consultation may be provided on items of public health significance.

8. Where applicable the principles and practices for prevention and control of vector problems associated with impoundments outlined in Appendix F be adhered to in the design, construction, and maintenance of the proposed Dodge Canyon Reservoir.

9. Where applicable the principles and practices for prevention and elimination of mosquito sources associated with irrigation outlined in Appendix G be adhered to in the development, operation, and maintenance of the project.

II. PUBLIC HEALTH AND RELATED PROBLEMS

Public Health Services

Project development will improve the economy of the area so that local residents benefiting either directly or indirectly will be in a position to enjoy a higher standard of living. Among other necessities, this involves the establishment of a healthful environment. Some of the more important factors in creating such an environment include the development of safe and ample culinary water supplies, proper waste disposal facilities, and insect and rodent control measures.

Public health services are provided in the project area by the Wyoming State Department of Public Health.

Recreational Development

Concomitant with the development of water resources comes the increased use of lands adjoining reservoirs for recreational purposes. This presents major problems of sanitation involving those of coordination of the multiple use policy and prevention of water pollution. The extent of recreational development, planned or spontaneous, immediately contiguous to reservoirs will be partially regulated by the topographical features of the shoreline. Also, a receding shoreline during the irrigation season, together with an accumulation of mud deposits above the water level, will create hazardous and undesirable conditions for some water-based recreational activities.

Construction Phase of Project

Limited housing accommodations are available in the vicinity of Dodge Canyon construction sites to serve the contractor's employees during the construction phase of the project. Under these conditions a temporary construction camp may be necessary. Prior to selection of a camp site a sanitary survey of the proposed area should be made by the State Department of Health, or the Public Health Service, to assist in solving of problems which may be encountered in connection with the installation of water and sanitary facilities.

Water supplies and sanitary facilities required in connection with temporary construction camps and with permanent housing for reservoir attendants should comply with the requirements of the Wyoming State Department of Public Health so as to eliminate potential health hazards.

Sanitary Aspects of Watershed Management

As overall watershed management involves many interests, it is considered essential that proposed developments and activities on watersheds pertaining to public health aspects be fully coordinated with State and/or local health departments. These matters should be mutually considered prior to the actual development of the watershed and issuance of permits.

Adequate and safe water and sanitary waste disposal facilities, in accordance with State and/or local health agency standards, should be provided in public use areas to serve camping, picnicking, and other recreational uses. Water and sanitary facilities for private dwelling sites should also meet the established health standards. The effectiveness of the sanitation program should be evaluated periodically by a detailed sanitary survey in conjunction with laboratory analyses of water samples collected from surface and/or ground water in the watershed.

On reservoirs construction primarily to serve as a source for a municipal water supply, extreme caution should be exercised in considering recreational use of the reservoir. This also involves the possibility of additional pollution entering the water supply and the matter of aesthetics.

Mosquito and Other Vector Problems

This preliminary vector evaluation is based on a review of information concerning the proposed Wheatland Unit, Laramie Division, Wyoming, obtained from the Bureau of Reclamation. Mosquitoes are the principal vectors which might be affected by the proposed project, although other insects and rodents may be involved. Several species of mosquitoes of public health importance, including Culex tarsalis, the encephalitis mosquito, and the vicious-biting Aedes vexans and Aedes dorsalis may be produced in the area when suitable aquatic habitats are present. Basic information concerning pertinent biological characteristics of these mosquitoes is given in Appendix B.

Encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States and the area in which the proposed project is located. Records of the U. S. Department of Agriculture show that equine encephalitis cases occurred in Platte and/or Albany County during 11 years of the 17-year period, 1939 through 1955, for which records are available. Although no outbreaks of human encephalitis have been recorded in these counties, the records of equine encephalitis cases indicate that the virus of encephalitis is active in the general area of the proposed project. Additional information concerning the public health and socio-economic importance of mosquito and other vector problems associated with water resource developments is presented in Appendix C.

Portions of the proposed Dodge Canyon Reservoir that have a steep shoreline with little or no vegetation and are exposed to wave action will be unfavorable for the production of mosquitoes and other aquatic insects of public health importance and will require no special vector prevention or control measures. Mosquito production may occur in embayments and other marginal areas of the reservoir where the topography is flat and the water is shallow, protected from wave action, and contains emergent vegetation or flotage. Information concerning reservoir preparation, maintenance, and water level management in relation to mosquito prevention and control is presented in Appendix D.

The proposed lining of project canals, rehabilitation of existing facilities, lowering of the high water table as a result of proposed pumping from new irrigation wells, and the anticipated improvement in irrigation practices should be of benefit to mosquito control. On the other hand, provision of additional water for irrigation, together with the inadequacy of existing drainage facilities, and failure to provide systems for the proper removal and disposal of excess water may aggravate existing mosquito sources and create new aquatic habitats favorable for mosquito production. Pertinent information concerning the relationships between irrigation and mosquito sources is presented in Appendix E.

By making provisions for the prevention and control of man-made vector sources, the overall benefits from the proposed project can be greatly increased.

Responsibility for Vector Control

Responsibility for vector prevention and control is normally associated with land ownership or operating rights. Therefore, the agency, group, or individuals responsible for various aspects of the proposed project should be prepared to accept full responsibility for the prevention and control of vector problems resulting from the design, construction, operation, or maintenance of the project.

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APPENDIX A

The following equation was derived by the Bureau of Reclamation for use in predicting future ground water quality in the Wheatland Flats, Wyoming:

$$P_t = \frac{P_i \ Q_i}{Q_d}\left[1-\left(1-\frac{P_o \ Q_d}{P_i \ Q_i}\right) e^{-\frac{Q_d t}{V}}\right]$$

P_t = dissolved solids in ground water at time t, mg/l

t = time in years

P_i = dissolved solids in surface water supply, mg/l

Q_i = quantity of surface supply at head of main project area, acre-feet/year

Q_d = outflow from ground water reservoir acre-feet/year

P_o = dissolved solids in ground water at beginning of period, mg/l

V = volume of ground water reservoir affected by pumping, acre-feet

The following values were used in making calculations of future ground water quality to be used in this report:

Item	Without Project	With Project
Q_i	55,600 acre-feet/year	77,900 acre-feet/year
P_i	500 mg/l	500 mg/l
Q_d	26,500 acre-feet/year	14,700 acre-feet/year
P_o	500 mg/l	500 mg/l
V	1,650,000 acre-feet	1,650,000 acre-feet

Some of the assumptions used by the Bureau of Reclamation in deriving the above equation are as follows:

1. A salt balance was assumed in the soil profile. The soil-salt concentration will not be disturbed by an increase in the concentration of dissolved salts in the irrigation water.

2. The project's return flow will be reduced by the volume of water needed to replace the water pumped for irrigation.

3. The gross surface area covering the ground water reservoir is estimated to be about 55,000 acres.

4. The assumed depth of the ground water reservoir affected by pumping is 100 feet.

5. The volume of voids in the ground water aquifer is assumed to be 20 percent of the total volume.

6. That block of land covering the ground water reservoir (55,000 acres) will be the only contributing area for the recharge of the subsurface reservoir.

7. The irrigable acreage of the 55,000 acre block is estimated to be about 45,000 acres.

8. For this study it was assumed that only the irrigation losses from the 45,000 irrigable acres and the farmer-operated lateral losses are available to recharge the ground water aquifer.

9. The project's distribution system losses were assumed to contribute directly to the projects return flow and they are not included in this study.

10. A period of 100 years is adequate for examining the quality of water conditions.

11. The average annual water supply is assumed to be delivered in each year for the main block of project lands. For purposes of the ground water operation study, the water supply for these lands was estimated to include 15,600 acre-feet of ground water pumped for irrigation and 77,900 acre-feet of surface water delivered to the canals serving the main block of project lands. The estimated consumptive use of this water is 64,000 acre-feet per year; the estimated return flow from the main project lands is 14,700 acre-feet per year after project development.

12. It was assumed that the average concentration of dissolved solids in the surface water would remain constant at 500 mg/l.

13. The concentration of dissolved solids in the ground water was assumed to be 470 mg/l at the beginning of the study period.

14. The farm irrigation losses are adequate to leach the increased concentration of dissolved solids through the soil to the ground water table. No portion of the dissolved material is precipitated in the aquifer, nor is any portion consumptively used by the crops.

15. Mixing of the recharge water with the water in storage in the ground water reservoir is assumed to take place instantaneously.

16. The concentration of the dissolved solids in the return flow and water pumped for irrigation will be the same as the concentration in the ground water.

APPENDIX B

BIOLOGY OF MOSQUITOES

This discussion is intended to provide only basic information concerning some of the more pertinent biological characteristics of mosquitoes commonly associated with water resource developments. These mosquitoes represent four important genera or groups: Anopheles, Culex, Aedes, and Psorophora. All mosquito species have four distinct stages in their life cycle: the egg, the larva, ("wiggler"), the pupa ("tumbler"), and the adult. A characteristic common to all mosquitoes is that they live in water continuously from the time the eggs hatch until the adults emerge. The aquatic stages generally occur in shallow water with an abundance of vegetation and flotage, and where they are protected from wave action. They do not occur in the deep open waters of lakes, ponds, or streams.

On the basis of egg-laying habits, mosquitoes may be divided into temporary-water and permanent-water species. The Aedes, and Psorophora are temporary water breeders which deposit their eggs on the moist soil of areas where surface water has receded. Hatching of the eggs is stimulated by subsequent floodings. The eggs may remain dormant for long periods, sometimes for several years if conditions are unfavorable for hatching. Normally, the eggs hatch more or less simultaneously soon after they are flooded. In contrast, the Anopheles and Culex usually lay their eggs on the surface of permanent and semipermanent bodies of water. The eggs usually hatch within a few days after oviposition. For both the temporary-water and permanent-water mosquitoes, time between hatching of eggs and emergence of adults varies with species and environmental conditions, especially water temperature. Development of the aquatic stages may be completed in as little as four days in hot weather while several weeks may be required in cool weather. Aedes and Psorophora mosquitoes generally develop more rapidly than the Anopheles and Culex.

Adult mosquitoes mate soon after emergence and the females begin seeking blood meals, which most species require before laying eggs. The biting habits of adult mosquitoes vary with species. Anopheles and Culex mosquitoes feed mainly at night while Aedes and Psorophora species feed both at night and in the daytime. Most species exhibit a peak of biting activity during a one- or two-hour period immediately after sundown. The Aedes and Psorophora species are aggressive and vicious biters of both man and livestock. Culex tarsalis, a vector of encephalitis, feeds readily on a wide range of hosts including man, wild and domestic birds, and livestock.

The flight range of mosquitoes varies widely with species and environmental conditions. The direction and distance of travel are greatly influenced by availability of food, shelter, and wind conditions.

Availability of food is probably the most important factor influencing the movement of mosquitoes in many areas. If an adequate food supply is close to the production sites, adult mosquitoes probably will not travel far from their sources. On the other hand, mosquitoes may travel several miles when adequate food supplies are not available nearer their larval habitats. The normal flight range of the Anopheles and Culex mosquitoes is usually considered to be about one mile, although recent studies have shown that certain species such as Culex tarsalis may travel several miles under certain environmental conditions. Most Aedes and Psorophora species are strong fliers and are known to range several miles from their larval habitats.

APPENDIX C

Public Health and Socio-Economic Importance of Vector Problems Associated with Water Resource Developments

Several groups of arthropods and rodents associated with the development and utilization of water resources may create serious public health and socio-economic problems. These include species that are vectors of disease organisms or serve as reservoirs of these organisms or which otherwise interfere with man's health and welfare.

Mosquitoes

Approximately a dozen species of mosquitoes of public health and socio-economic importance may be produced in habitats associated with irrigation, impoundments, and other water resource developments. Encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States. Mosquitoes obtain the encephalitis viruses from wild vertebrates and then transmit them to horses and humans. There are no effective chemotherapeutic measures for preventing or treating human cases; and some individuals, particularly children, who recover from encephalitis often suffer permanent mental disability. Three principal types of mosquito-borne encephalitis occur in the United States. Eastern encephalitis (EE) occurs mainly in the Atlantic and Gulf Coast States from New Hampshire to Texas, but sometimes extends as far inland as Wisconsin. St. Louis encephalitis (SLE) occurs chiefly west of the Mississippi River and in several of the Central States. The third type, western encephalitis (WE), is confined primarily to the states west of the Mississippi River.

Culiseta melanura and several species of Aedes mosquitoes are believed to be involved in the transmission of EE. The principal vector of both WE and SLE in the Far West is Culex tarsalis, a mosquito which is widely distributed west of the Mississippi River. In the Central States, Culex pipiens and Culex quinquefasciatus are believed to be important in the transmission of SLE. Aedes and other mosquitoes may also be involved as secondary vectors of encephalitis. Both western and St. Louis encephalitis are endemic in many western areas, and outbreaks of WE among horses and of WE and SLE among humans have been rather widespread. In recent years, outbreaks of encephalitis have occurred in irrigated areas in the Texas High Plains (1956), in the Intermountain States (1957), in the Lower Rio Grande Valley (1957), in Utah and New Mexico (1958), and in Wyoming (1960).

The occurrence of malaria outbreaks as a result of improperly prepared reservoirs in the Southeastern States is well documented. Malaria has also been associated with irrigation in several states including California, New Mexico, Texas, and in the rice-growing areas of the Mississippi Delta. This disease has been almost eradicated from the United States; and at present, there is no significant malaria transmission anywhere in the Nation. The malaria vectors (Anopheles quadrimaculatus in the East and Anopheles freeborni in the West) are still prevalent in some areas where favorable habitats are present. These mosquitoes constitute a potential hazard for the establishment of new foci of malaria transmission, particularly in situations where the disease may be reintroduced from foreign countries. This was well illustrated at Lake Vera in California during the summer of 1952, where 35 cases of malaria occurred among Camp Fire Girls. The source of their infections was traced to a soldier who had an attack of malaria while camping at the lake.

Several vicious-biting species including Aedes vexans, Aedes dorsalis, and Aedes nigromaculis may be produced in habitats associated with irrigation and other water resource projects. These mosquitoes often create public health problems aside from the transmission of specific diseases. Such health hazards are illustrated by the results of surveys made by the United States Public Health Service in irrigated areas in northern Montana. In three-fourths of the families surveyed, mosquitoes severely annoyed both adults and children and interfered with their normal outdoor activities during the summer months. Mosquito bites causes some degree of injurious reaction in 8 out of 10 people interviewed; and in one section, 40% of the individuals examined by the physician showed evidence of secondary infection of mosquito bites. Some individuals, particularly children, frequently required medical attention and sometimes even hospitalization for treatment of secondary infections and occasional allergic reactions caused by mosquito bites.

In addition to their public health importance, mosquitoes often create other serious problems in both rural and urban areas. Their vicious biting reduces the efficiency of farm workers and sometimes hinders the harvesting of crops. Dense populations of attacking mosquitoes have been reported to kill livestock. The constant attacks of even moderate populations of these insects may reduce the vitality of farm animals and prevent proper feeding, thereby causing weight gains and lower milk and egg production. Mosquitoes are vectors of encephalitis, anaplasmosis, fowl pox, and several other important diseases of animals. These diseases kill large numbers of farm animals each years. Together, mosquito annoyance and mosquito-transmitted diseases undoubtedly result in losses of millions of dollars to farmers every year.

Large numbers of biting mosquitoes also cause serious economic losses by reducing the efficiency of industrial workers, lessening the value of real estate, restricting outdoor recreational activities, and reducing attendance at outdoor business establishments such as drive-in theatres and eating places.

The economic magnitude of the irrigation-mosquito problem alone is illustrated by expenditures for abatement of these insects. For example, in California over $5,000,000 is spent annually to control encephalitis and other irrigation mosquitoes and it has been estimated that at least twice this amount would be required to provide adequate control throughout the State. Approximately $200,000 is spend each year for mosquito abatement in a few irrigated areas in Utah. Many urban communities in other western irrigated areas spend large sums of money each season for chemical control to provide partial protection from mosquitoes. Individual families also spend sizable amounts of money each summer for household sprays, mosquito repellents, livestock sprays, and medicine for treatment of mosquito bites. The total cost of controlling irrigation mosquitoes, together with the other serious economic losses they cause, runs into many millions of dollars each year. Thus, mosquitoes are a major economic liability in many irrigated areas.

Other Aquatic Insects

Several other groups of aquatic insects may be produced in sufficient numbers in habitats associated with water resource projects to create public health and economic problems. Deer flies and horse flies (Tabanidae) are produced along the margins of impoundments and in seeps and marshes in irrigated areas. These insects are vicious biters of both man and livestock and are sometimes involved in the transmission of diseases such as tularemia and anthrax. Some species of small gnats of the family Heleidae are also vicious biters and often produce severe reactions and vesicular lesions. These gnats are produced in damp areas of many irrigated valleys as well as salt marshes and other wetland areas. In certain areas, black flies (Simuliidae) plague both man and livestock with their irritating and painful bites. They are normally produced in streams but sometimes occur in large numbers in irrigation conveyance systems. The small nonbiting midges (Tenipedidae) and the phantom midges (Chaoborinae) are another group of pestiferous insects which may be produced in impounded water. These insects are attracted to lights in tremendous numbers and cause severe human annoyance. An example is the Clear Lake gnat, Chaoborus astictopus, which creates serious problems at the resort areas in Lake County, California.

Terrestrial Arthropods and Rodents

Each summer, many millions of people visit picnic sites, campgrounds, cabins, and other water-related recreational facilities along the shores of reservoirs. In addition to mosquitoes and other insects of aquatic origin, these people are often exposed to terrestrial arthropods such as ticks, mites, fleas, and flies and rodents, including ground squirrels, rats, mice, and chipmunks. The public health importance of these arthropods and rodents involves a number of human diseases including Rocky Mountain spotted fever, Colorado tick fever, tularemia, relapsing fever, tick paralysis, typhus, plague, bacillary dysentery, and typhoid. The bites of certain arthropods also cause considerable irritation, discomfort, and annoyance.

APPENDIX D

Reservoir Preparation, Maintenance, and Water Level Management in Relation to Mosquito Prevention and Control

Man-made impoundments range in size from large multipurpose reservoirs with thousands of acres to small farm ponds of less than an acre. Mosquito-producing conditions associated with both large and small impoundments are basically similar but vary greatly in magnitude. They include emergent vegetation and/or floating debris in shallow water areas which are protected from wave action; undrained depressions, borrow pits, sloughs, and marshes within the summer fluctuation zone; and rising or constant pool levels which cause the water to remain in relatively flat areas with vegetation for more than four or five consecutive days during the mosquito production season. Several species of Anopheles and Culex mosquitoes, including Culex tarsalis, are frequently produced in impoundments that have protected shallow water areas with emergent vegetation and/or flotage. The flat vegetated areas of reservoirs and ponds, which are alternately inundated and exposed by fluctuating water levels, may also be highly favorable for the production of several species of Aedes and Psorophora mosquitoes. Aedes vexans is one of the most common and widespread of these species. It is almost axiomatic that reservoirs and ponds which are free of vegetation and flotage do not produce mosquitoes.

It is often difficult to control mosquito production on a reservoir that has not been properly prepared prior to impoundage. Clearing and drainage are the principal reservoir preparation measures for mosquito prevention and control. The overall objective of these measures is to prevent or minimize the development of favorable mosquito-producing habitats in any portion of the reservoir which is within flight range of human population.

Clearing includes removal of trees, underbrush, vines, fences, and debris from the reservoir basin. For mosquito control purposes, the normal summer fluctuation zone should be completely cleared except for isolated trees and sparse vegetation located along abrupt shorelines that will be exposed to wave action. It is not necessary to clear timber from the deeper portions of the reservoir basin where it will be completely submerged at normal summer minimum pool elevation. Timber rooted below the normal summer minimum pool level but extending above that elevation may be felled and securely tied down in lieu of disposal. This practice sometimes has advantages in fisheries management. Where clearing operations extend over several seasons, it is sometimes necessary to remove regrowth from the normal summer fluctuation zone immediately prior to impoundage.

Borrow pits, depressions, marshes, and sloughs which will be flooded when the reservoir is at maximum pool level and which will retain water at lower pool levels may be serious mosquito sources. Drainage ditches should be provided for all such areas, particularly those located within the normal summer fluctuation zone. These ditches should insure complete drainage of the areas when the reservoir recedes and permit fluctuation of water levels in them when the reservoir is at higher elevation. Such drainage ditches may also serve to prevent the stranding of fish when the lake recedes. Logs, drift, and other debris should be removed from natural drainageways and existing ditches where such work is indicated for mosquito prevention and control. Permanent shoreline improvement measures can sometimes be employed to eliminate mosquito-producing areas in reservoirs when the normal summer fluctuation zone is limited to a few feet.

Since the effectiveness of naturalistic, preventive, and permanent mosquito control measures is determined by the amount of clean water surface they create, it is essential that ponds and reservoirs be properly maintained after they have been impounded. Furthermore, maximum mosquito control benefits from water level management can be realized only when impoundments are properly prepared and maintained. Several phases of water level control, such as flood surcharge, constant level pool, cyclical fluctuation, and/or seasonal recession, can sometimes be adapted to various types of impoundments in order to minimize conditions favorable for mosquito production. Certain phases may be used to control vegetation and flotage or they may be used primarily to destroy mosquito larvae. A flood surcharge above the upper normal pool level for a few days in the spring prior to the mosquito production season followed by a sharp drawdown is effective in stranding objectionable flotage. The invasion of marginal vegetation can be limited by holding the reservoir at a constant level during the early spring growth period. This phase is especially important since it increases the effectiveness of subsequent fluctuation and/or recession. Seasonal water level recession alone or in combination with periodic fluctuation is an effective control measure since it provides a clean shoreline which is unfavorable for mosquito production. In some irrigation storage reservoirs, the normal water releases during the growing season usually result in a drawdown that keeps the pool level below encroaching marginal vegetation, thereby providing a clean shoreline that is unfavorable for mosquito production.

Recreational areas, especially those with facilities where people may remain overnight, should be located along sections of the reservoir which have the lowest potential for the production of mosquitoes and other aquatic insects of public health importance. Proper consideration should also be given to terrestrial vector problems in selecting recreational sites. Where necessary, full provision should be made for the prevention and control of both types of vector problems.

APPENDIX E

Relationships Between Irrigation and Mosquito Sources

The production of mosquitoes and other aquatic insects of public health importance occurs in many western irrigation areas, particularly where the water is applied by surface methods. Natural mosquito habitats are present in most irrigated areas, but usually man-made mosquito sources are far more important. These man-made aquatic habitats are frequently caused by the same faulty irrigation and drainage practices that result in serious soil and water problems such as excessive water losses, waterlogging, erosion, salt and alkali accumulations, damage to soil structure, leaching of plant nutrients, and reduced crop yields. Some of the "on-field" and "off-field" mosquito sources commonly associated with irrigation in the west are briefly discussed in the following sections.

On-Field Mosquito Sources

Prolific mosquito production occurs in low areas on fields used for pastures, hay meadows, and other close-growing forage crops where irrigation water often remains ponded long enough for the larvae to mature. Mosquitoes are sometimes produced on fields planted to irrigated row crops such as cotton, but usually ponded water is not present on these fields long enough for the aquatic stages to complete their development. Surface water must be present for at least 4 or 5 days in order for the aquatic stages to mature and produce adult mosquitoes. Rice is the only field crop that thrives when flooded this long. Observations in several areas have shown that when irrigation water is ponded on pastures and hay meadows long enough to produce mosquitoes, the desirable forage grasses and legumes are frequently killed and replaced by undesirable wetland plants. Thus, the extended flooding which is conducive to mosquito production is unfavorable for satisfactory growth of the common field crops.

In California, tremendous numbers of Aedes nigromaculis are produced in the ponded areas on irrigated pastures. Some of these pastures are irrigated 10 to 15 times from April through October and a brood of mosquitoes may be produced in the ponded water that remains after each irrigation. Investigations in the Milk River Valley of northern Montana showed that over two-thirds of all mosquito production (mostly Aedes dorsalis and Aedes vexans) on a 5,000-acre study area occurred in ponded areas on irrigated alfalfa fields, pastures, and western wheat grass meadows. In this valley, the irrigation water frequently remains ponded on the hay meadows long enough to produce Culex tarsalis, the encephalitis mosquito. Studies in Nebraska showed that large numbers of both Culex tarsalis and Aedes mosquitoes are produced in ponded areas on irrigated pastures and hay meadows along the North Platte River. The use of irrigated mountain

meadows for the production of hay and supplemental grazing of livestock is widespread in the Rocky Mountain States. In many of the mountain valleys, the bottomland meadows are flooded almost continuously throughout the spring and early summer months. Ponding also occurs in numerous low areas following irrigation later in the season. The extensive aquatic habitats that occur on many irrigated mountain meadows produce tremendous numbers of encephalitis and other irrigation mosquitoes.

In addition to the depressions on irrigated fields, water sometimes remains ponded in the field laterals and drains long enough to produce encephalitis and other irrigation mosquitoes. This type of mosquito source occurs most often in areas having fine textured soils and poor underdrainage. Field laterals and drains that contain excessive amounts of vegetation are more favorable for mosquito production. Mosquitoes may also be produced in the residual water in various hydraulic structures, such as drops in ditches, particularly when they contain tumbleweeds and other debris. Mosquito production in hydraulic structures is usually of minor importance in comparison with that which occurs in other types of "on-field" aquatic habitats.

Rice fields constitute a special type of "on-field" mosquito source, since the flooding used for growing rice is very favorable for mosquito production. In rice fields of the Mississippi Delta and Gulf Coast areas, large numbers of Psorophora confinnis and Psorophora discolor are produced by intermittent irrigation; and Anopheles quadrimaculacus, the malaria mosquito, is produced in the constantly flooded rice fields. Rice fields in California are usually flooded throughout the growing season and they provide favorable aquatic habitats for production of Culex tarsalis, the encephalitis mosquito, and Anopheles freeborni, the western malaria mosquito. Large numbers of Aedes nigromaculis and Aedes dorsalis mosquitoes are frequently produced by the initial flooding of rice fields in California.

Off-Field Mosquito Sources

In many western irrigated areas, widespread and prolific mosquito production occurs in a variety of aquatic habitats located outside the boundaries of irrigated fields. These mosquito sources include roadside ditches, borrow pits, depressions on nonirrigable land, and numerous other undrained areas that are flooded by surface runoff from irrigated fields and other excess irrigation water. Such aquatic habitats often contain dense vegetation which makes them more favorable for mosquito production. The semipermanent and permanent water areas are highly favorable for Culex tarsalis, the encephalitis mosquito. Those with fluctuating water levels produce large numbers of this mosquito as well as several vicious-biting Aedes species.

The types of "off-field" habitats just described accounted for more than one-fourth of the total mosquito production on a 5,000-acre study area in the Milk River Valley of northern Montana. In the North Platte Valley of western Nebraska, wasteland areas, roadside ditches, borrow pits and other undrained areas flooded by runoff from irrigated fields and overflow from conveyance systems were found to be important sources of both Culex tarsalis and Aedes mosquitoes. Playas or land-locked depressions, flooded by runoff from irrigated fields, were responsible for three-fourths of all mosquito production on study areas in the Texas High Plains. These playas produced large numbers of Culex tarsalis and several other species of irrigation mosquitoes. In certain western areas, large nonirrigable areas are wildly flooded with excess irrigation water for use by ducks and other waterfowl. Such areas are highly favorable for the production of tremendous numbers of Aedes mosquitoes. Several of the abatement districts in California and Utah spend large sums each year to control mosquitoes produced on waterfowl areas of this type.

Mosquito sources are often associated with the main irrigation conveyance systems, portions of which are sometimes located on nonirrigable lands. A large amount of irrigation water is often lost by seepage and leakage through the beds and banks of unlined canals and laterals which are located in pervious material. In areas having poor underdrainage, these seepage losses alone or in combination with deep percolation from irrigated fields often result in marshes and ponded water in roadside ditches, borrow pits, and other areas. In many western irrigated areas, aquatic habitats created by seepage produce large numbers of mosquitoes. Permanent and semipermanent seepage areas have been found to be especially favorable for the production of Culex tarsalis, a vector of encephalitis. Large numbers of Aedes mosquitoes are also produced in seepage areas that have fluctuating water levels.

Mosquito production may also occur in various other "off-field" aquatic habitats associated with the main irrigation conveyance systems. These mosquito sources include flooded areas resulting from overflow of poorly maintained canals and laterals; ponded areas where conveyance channels block natural drainageways; residual water in turnouts, stilling basins, and other hydraulic structures; surface pools created by leakage from water control structures; and residual water in conveyance channels during nonoperational periods. Although these types of aquatic habitat contribute to the total mosquito problem, they are generally of less importance than those caused by seepage and the numerous other "off-field" mosquito sources.

APPENDIX F

Principles and Practices for Prevention and Control of Vector Problems Associated with Reservoirs

I. Prevention and Source Reduction Measures

A. For Mosquitoes and Other Aquatic Insects

1. All borrow pits and other potential ponding areas associated with construction of the dam, relocation of highways or roads, etc., which are located above maximum pool level should be made self-draining.

2. Prior to impoundage, the reservoir basins should be prepared as follows:

   a. The normal summer fluctuation zone of the permanent pool should be completely cleared except for isolated trees and sparse vegetation along abrupt shorelines which will be exposed to wave action.

   b. Dense stands of timber rooted below the normal summer minimum pool level but extending above that elevation should be cleared. In some situations, such timber may be felled and securely tied down in lieu of disposal.

   c. Borrow pits, depressions, marshes, and sloughs which will be flooded by the reservoir at maximum pool level and which would retain water at lower pool levels should be provided with drains to insure complete drainage or fluctuation of water within them.

   d. If the summer fluctuation zone of the permanent pool is limited to a few feet, consideration should be given to "building out" mosquito-producing areas located within flight range of population groups or recreational areas tnrough the use of measures such as deepening and/or filling. This would minimize the need for repetitive measures for controlling vegetation and mosquito production.

3. After impoundage, the following maintenance measures should be carried out in all potential mosquito-producing areas located within flight range of human population groups or recreational areas frequented by significant numbers of persons:

   a. All dense vegetation should be removed periodically from flat, protected areas within the normal summer fluctuation zone of the permanent pool.

b. Vegetation, debris, and flotage should be removed periodically from all drains to insure free flows.

4. Water level management to minimize conditions favorable for mosquito production should be used to the maximum degree permitted by the primary purposes of the reservoir. This will minimize the need for repetitive measures for controlling vegetation and mosquito production.

5. As a general principle, waterside recreational areas, particularly those which have facilities for overnight human occupancy, should be located along sections of the reservoir which have a low production potential for mosquitoes and other aquatic insects of public health importance.

B. For Terrestrial Arthropods and Rodents at Recreational Areas

1. Proper storage, collection, and disposal of refuse should be practiced in order to prevent and control flies, wasps, other noxious insects, rats, wild rodents, and other small mammals.

2. All buildings should be rodentproofed at recreational areas where rodents are prevalent which may create public health hazards.

3. Debris, rubbish, and other materials which may serve as harborage for rodents and other small mammals should be removed periodically.

4. Brush and weeds along paths, trails, roadways, and other areas of frequent use by visitors should be removed in order to reduce the likelihood of tick infestation.

II. Supplemental Chemical Control Measures

In situations where adequate vector control is not obtained through prevention and source reduction measures, provision should be made for supplemental use of insecticides and rodenticides to achieve the desired level of control.

III. Vector Appraisal

Arrangements should be made for carrying out a routine program of vector appraisal as a part of normal operations of the reservoir and associated recreational areas. Inspections for adult and larval mosquitoes and other vectors are essential for planning and evaluating control measures and for adjusting control programs to meet temporary or emergency situations.

APPENDIX G

Principles and Practices for Prevention and Elimination of Mosquito Sources Associated with Irrigation

A. Project Conveyance and Distribution Systems

1. Lining or other satisfactory seepage control measures should be provided for all sections of canals and laterals located in porous material where excessive leakage would result in waterlogged areas, seeps, and ponds.

2. Drains should be installed to prevent ponding of excess irrigation water and natural runoff along the upper side of canals and laterals. All drainage crossing or inlet structures should be placed on grade to avoid ponding.

3. Borrow areas should be self-draining to keep them from retaining ponded water.

4. Where possible, provision should be made to prevent turnouts and other hydraulic structures from retaining residual water when they are not being used.

5. Effective measures should be provided to prevent ponding of leakage from water control structures.

6. Every effort should be made to establish delivery schedules which will provide farmers with adequate but not excessive amounts of water at proper intervals to insure efficient irrigation of the crops concerned.

7. Vegetation and debris which would retard normal flows should be periodically removed from conveyance channels, water control structures, and drains.

B. Project Drainage Systems

1. Trunk drainage systems should be installed to insure complete removal and proper disposal of excess irrigation water, natural runoff, and seepage from both irrigable and nonirrigable lands affected by the distribution and use of irrigation water on the project.

2. Drainage ditches should be designed, constructed, and maintained so as to minimize ponding in the channels and to insure free flows at all times.

3. Provision should be made to prevent water from ponding behind spoil banks.

4. Underdrains, culverts, inlets, etc., should be placed on grade to prevent ponding.

C. Irrigated Farms

1. The sponsoring agency and other organizations concerned with irrigation agriculture or mosquito control should do everything possible to encourage irrigation farmers to use the following irrigation and drainage practices which will prevent or minimize mosquito sources:

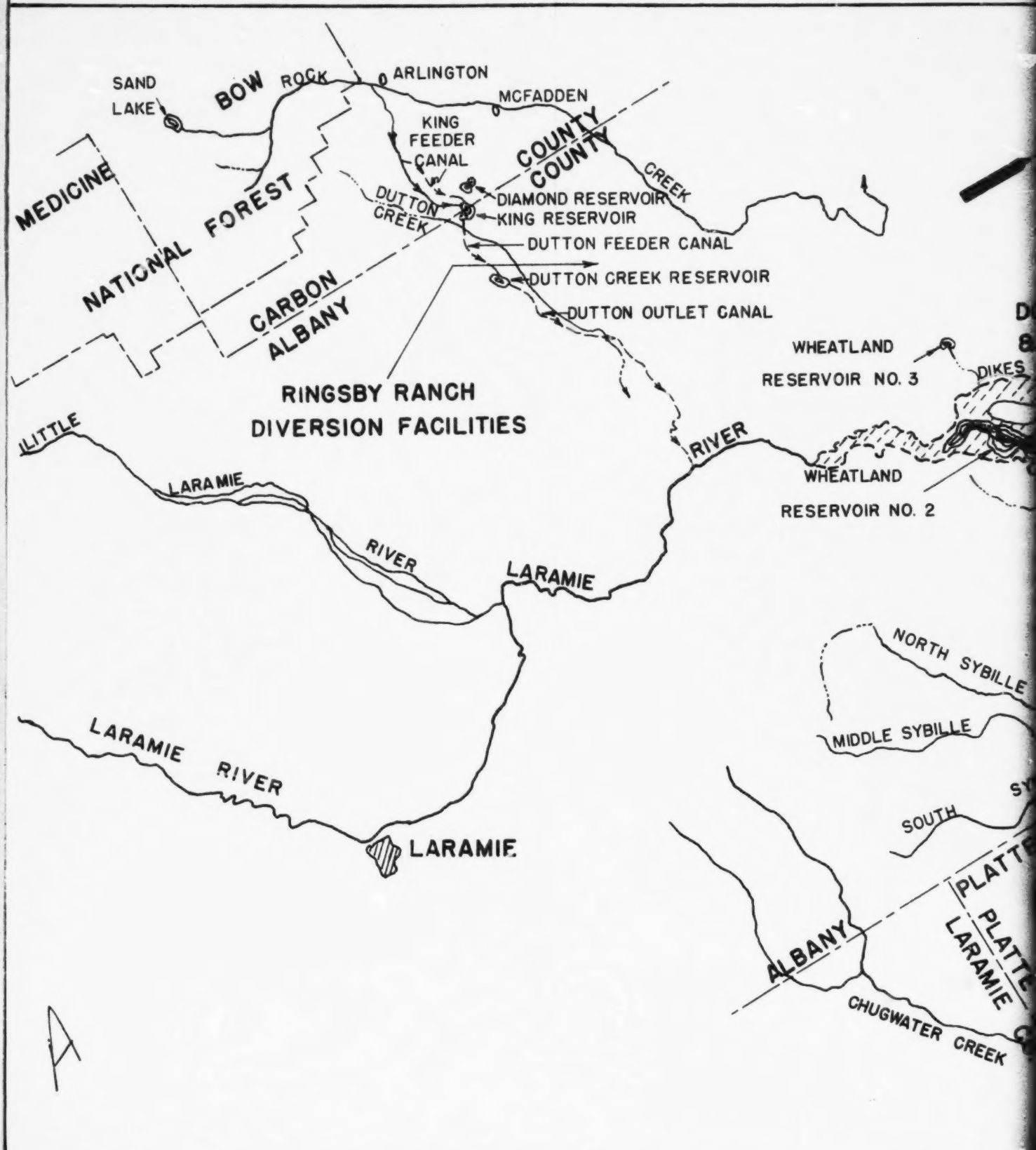
   a. The farm supply system, drainage system, and field layouts should be properly fitted to the topography, soil, water supply, crops to be grown, and irrigation methods to be used.

   b. All surface irrigated fields should be properly leveled or graded to provide for efficient water application and removal of excess water without ponding.

   c. An adequate drainage system should be provided for removal of excess water from all portions of the farm.

   d. Irrigation methods should be used which will provide optimum irrigation efficiencies.

   e. Application of irrigation water should be limited to that required to fill the crop root zone plus unavoidable losses and excess water needed to prevent upward movement of salts.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ARLINGTON
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COUNTY
COUNTY
CREEK
MEDICINE
NATIONAL FOREST
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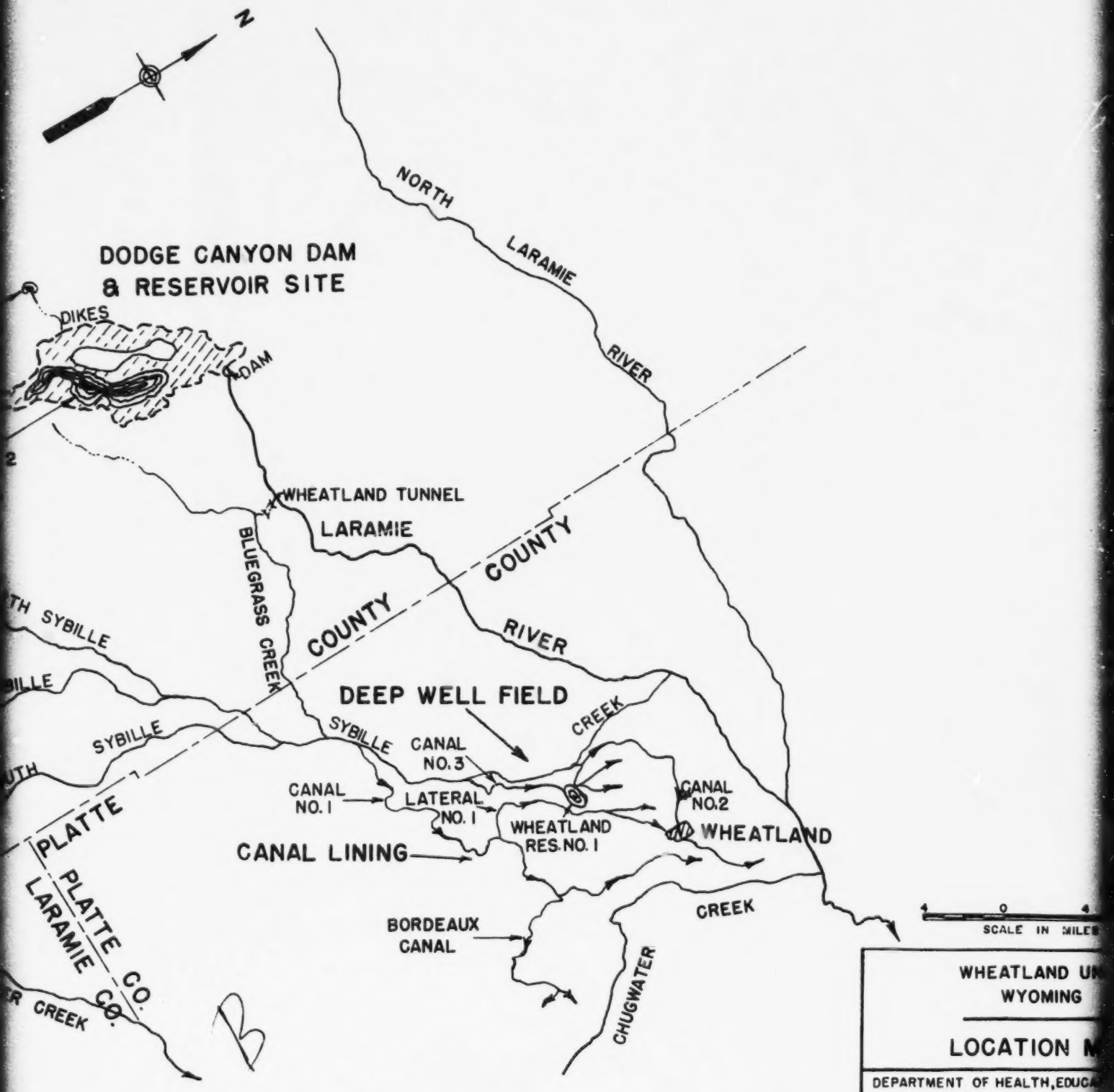
DIAMOND RESERVOIR
KING RESERVOIR
DUTTON FEEDER CANAL
DUTTON CREEK RESERVOIR
DUTTON OUTLET CANAL
CARBON
ALBANY
WHEATLAND RESERVOIR NO. 3
DIKES
RINGSBY RANCH DIVERSION FACILITIES
LITTLE LARAMIE RIVER
RIVER
WHEATLAND RESERVOIR NO. 2
LARAMIE
NORTH SYBILLE
MIDDLE SYBILLE
LARAMIE RIVER
SOUTH
PLATTE
ALBANY
LARAMIE
CHUGWATER CREEK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NORTH LARAMIE RIVER
DODGE CANYON DAM & RESERVOIR SITE
DIKES
DAM
WHEATLAND TUNNEL
LARAMIE COUNTY
BLUEGRASS CREEK
SYBILLE
DEEP WELL FIELD
CANAL NO. 3
CANAL NO. 1
LATERAL NO. 1
WHEATLAND RES. NO. 1
CANAL NO. 2
WHEATLAND
CANAL LINING
PLATTE
PLATTE CO.
LARAMIE CO.
BORDEAUX CANAL
CHUGWATER
CREEK
SCALE IN MILES
WHEATLAND UN
WYOMING
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NO. 1
WHEATLAND
RES. NO. 1
CANAL
NO. 2
WHEATLAND
AL LINING
BORDEAUX
CANAL
CREEK
CHUGWATER
4 0 4 8
SCALE IN MILES
WHEATLAND UNIT
WYOMING
LOCATION MAP
DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO

FIGURE 1